Phreatic Karst Conduit Turbulent Flow
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Most phreatic conduit flow is turbulent (White and White, 2005). Prof. Will White, a senior karst researcher states: "Ground water flow in conduits is localized and under normal gradients flows in a turbulent regime. The onset of the non-Darcian behavior occurs when the aperture exceeds about 1 cm" ((White, 2002), p. 90, first full paragraph). Usually Reynolds number is used to differentiate between laminar or turbulent flow. Reynolds number, Re, is the ratio of inertial to viscous forces in a fluid (Landau and Lifshitz, 1987). For a pipe it is given by:

$$Re = \frac{QD}{\nu A} \tag{1}$$

where: Q is the average discharge [length time^{-3}]; D is the diameter of the pipe [length]; ν is the kinematic viscosity of the fluid [length^2 time^{-1}]; and A is the pipes cross-sectional area [length^2]. Recalling that Q/A gives v, velocity [length time^{-1}], and substituting we get:

$$Re = \frac{vD}{\nu} \tag{2}$$

Water, at 20°C, has a kinematic viscosity of roughly $10^{-4}\,\mathrm{m^2 s^{-1}}$. This allows us then to make a plot of Reynolds Number for given conduit dimeters and flow rates, Figure 1. At small conduit diameters and small velocities flow is non-turbulent; it obeys Darcy's Law. Flow is turbulent if the Reynolds number is greater than 2,000 (Landau and Lifshitz, 1987).

Since turbulent flow can have several appearances we recommend the classic flow visualization video: `http://modular.mit.edu:8080/ramgen/ifluids/Turbulence.rm`. .

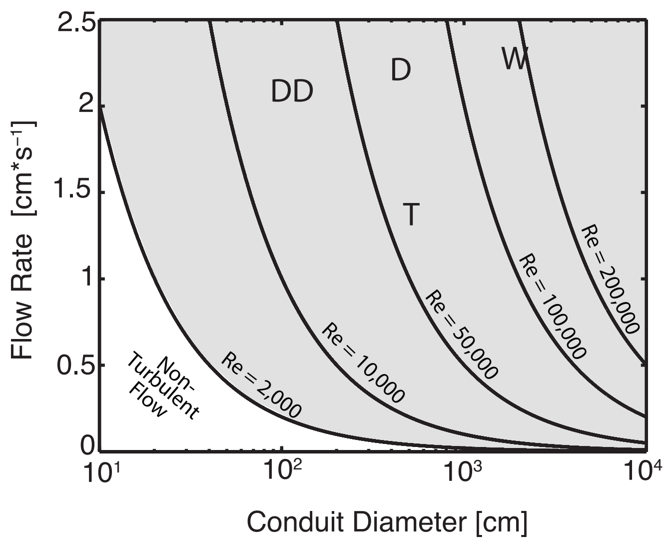

Figure 1: Karst Conduit Turbulent Flow. Shaded area shows turbulent flow with Reynolds numbers plotted. Typical phreatic Florida caves labeled: DD) Twin Dee's, discharge on 5 Mar. 03; D) Devil's Ear, discharge on 5 Sep. 01; W) Wakulla, average discharge from 1907-1974; T: Telford, discharge on 17 Sep. 97. Unpublished plot by Koski, discharge data from Scott et al. (2004)

References

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